GEOCHEMISTRY AND HEAT GENERATION IN THE DURANDAL ADAMELLITE AT YETHOLME, NEW SOUTH WALES

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Synopsis

The Bathurst batholith outcrops over about 1600 km^2 in central western New South Wales and is a complex of several granitic intrusions. Two small satellitic stocks outcrop near Yetholme and the western stock has been sampled for geochemical studies. Palaeomagnetic and radiometric studies established a late Carboniferous age (about 312 My) for this body, confirming earlier radiometric and stratigraphic dating of the batholith.

Although described previously as the " Yetholme Granite ", modal data indicate that the main rock type in these stocks is an adamellite. The name " Yetholme adamellite " has been used, but it is proposed to term these two stocks the *Durandal Adamellite* and the *Eusdale Adamellite*. The *Durandal Adamellite* was the only body sampled for this investigation. Minor rock types include aplite and dolerite or microdiorite ; and xenoliths are present in the adamellite. The adamellite is porphyritic, with large crystals (megacrysts) of potash feldspar up to 7 cm in length comprising about 10 percent of the rock. They have grown across some of the contacts of enclosed xenoliths. Chemical analyses, including trace element data, of all phases and of potash feldspar separated from the adamellite, a pegmatite phase and xenoliths support earlier conclusions (Mackay, 1964) that the megacrysts developed *in situ* in an apparent closed system of late-stage ionic fluids which partly replaced early-formed crystals.

Heat generation by the *Durandal Adamellite* is $2 \cdot 96$ μW/m^3, which is similar to that calculated for the Bathurst batholith. These values are high compared to other data presently available from similar rock types in New South Wales.

INTRODUCTION

The western edge of the Sydney Basin overlaps early, middle and late Palaeozoic rocks, including the intrusive rocks of the Bathurst batholith (Fig. 1). Vallance (1969) summarised the geology of the batholith, an intrusive complex which is elongate roughly east-west cutting across the general north-south trending Ordovician to Devonian rocks of the Capertee Rise and Hill End Trough. The overlying Sydney Basin rocks are of Permian age. Rocks of the composite batholith are typically massive, and range from mafic phases (for example the gabbros described by Joplin (1931, 1944) from near Hartley) through to granites and adamellites.

Radiometric dating of granite from the eastern end of the batholith gave a Carboniferous age of 315 My. This is the average of two determinations by Evernden and Richards (1962) using K-Ar techniques, recalculated by Cas *et al.* (1976, p. 205) using " preferred decay constants ". Hirt *et al.* (1963) gave a Re-Os age of 330±40 My for molybdenite from a skarn at Yetholme (Mt. Tennyson). As the molybdenite mineralisation was apparently introduced by emplacement of the main phase of the batholith, or by the satellite intrusion at Yetholme (Vallance, 1969), the Re-Os (molybdenite) age is probably that of the batholith. K-Ar and Rb-Sr dating (Facer, 1976) of adamellite, aplite and a " doleritic " dyke from the small intrusion at Yetholme gave ages ranging from 298±10 My to 325±17 My. There is thus good evidence to indicate that the Bathurst batholith was emplaced approximately 312 My ago. However. the batholith outcrops over an area in excess of 1600 km^2 (Vallance, 1969), and is a complex of a number of cross-cutting as well as discrete intrusions,the relations of which are not fully understood.

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At Yetholme Mackay (1964) mapped in detail two stocks of granite (or adamellite), which are apparently satellites of the batholith (Fig. 1). These two stocks, which are of the same rock type (Mackay, 1964), may be connected at depth. This rock has been known informally as the " Yetholme Granite ", and has also been termed the " Yetholme adamellite " (Phillips and Carr, 1973). Mackay (1964) used the terms Durandal Stock and Eusdale Stock (Fig. 1) for the two stocks, and Watts (1969) also used the term Durandal Stock. These two adamellite bodies are termed in this investigation the Durandal Adamellite and the Eusdale Adamellite.

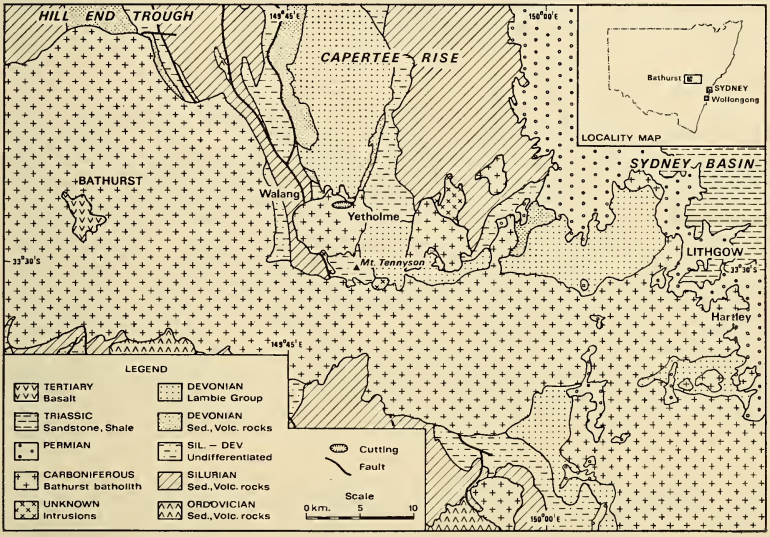

Fig. 1. Geological map of the Bathurst batholith and the rocks into which it is emplaced (with locality map inset), based on Bryan (1966) and Packham (1968). Outcrop of the batholith extends approximately 5 km southeast and 15 km west of that shown here, and one or two minor separate outcrops have been omitted. The Durandal Adamellite and Eusdale Adamellite are the two stocks outcropping near Yetholme, with the road-cutting sampled for this investigation shown in the Durandal Adamellite. Mackay (1964) named these two stocks the "Eusdale stock" (eastern) and the "Durandal stock". These have been termed the "Eusdah" and "Duronal" stocks respectively in Packham (1968), and on subsequent maps (J. Hawke, personal communication, 1977).

During 1970 a new road-cutting was made through the Durandal Adamellite. This cutting, 0·3 km long and up to 8 m deep, exposed fresh adamellite cut by narrow aplite veins up to 12 cm wide, a " dolerite " dyke 30 cm wide and one highly altered dyke of unrecognisable rock type. The opportunity was taken to sample these rocks for detailed investigation encompassing petrology and geochemistry, radiometric dating and palaeomagnetism (Facer, 1976, 1977).

GEOLOGY OF THE DURANDAL ADAMELLITE

The Durandal Adamellite has a roughly circular outcrop about 6 km in diameter (Fig. 1). It has been emplaced into rocks of Silurian (dated by Cas *et al.*, 1976) and Devonian age, including volcanic rocks, shales, greywackes and sandstones. Limestones are present in the Silurian rocks and locally these have been altered to hornfelses and skarns either by the adamellite or the main part of the Bathurst batholith, or both. Detailed descriptions of these rocks have been given by Mackay (1964) and Watts (1969). More recently Wright and Ghent (1973) described metamorphosed fossils from a hornfels just north of the Durandal Adamellite (at Walang), and Phillips and Carr (1973) discussed myrmekites from the Durandal Adamellite.

GENERAL PETROGRAPHY

Mackay (1964) has given comprehensive petrographic descriptions of the three main rock types from the adamellite at Yetholme. However, these three are apparently only variations of the overall adamellite rock type. The chilled marginal phase is very minor (described by Mackay (1964, p. 5) as being " modally adamellites ") and the other two (described by Mackay (1964) as granites) are differentiated only on the basis of the presence of large potash feldspar megacrysts. Mackay (1964) has called these two types " megacrystalline granite " and " normal granite ", the latter containing no more than 1% of potash feldspar megacrysts and occurring as an apparent core to the intrusion. On the basis of samples from the road-cutting near the north-western edge Phillips and Carr (1973) used the term " adamellite " for this rock. Table 1 contains an indication of the modal composition of samples from the stock, the data being based partly on the large number of determinations by Mackay (1964). It can be seen in column 2 of Table 1 that the potash feldspar content is very close to that of the plagioclase, and hence the rock is an adamellite, although Mackay (1964) has shown that the megacrysts had a late-stage formation. (These feldspar proportions become equal if the megacrysts comprise 11·5% of the total.) The " normal granite " (Table 1) has a more granitic mode, but is still an adamellite. However, " normal granite " is noticeably subordinate to the " megacrystal " phase (Mackay, 1964, Fig. 2). On the basis of the near-equality of potash feldspar and plagioclase, the term *Durandal Adamellite* is used here. Similarly, using the data of Mackay (1964), the term *Eusdale Adamellite* is used for the eastern stock.

MINERALOGY OF THE DURANDAL ADAMELLITE

Because only the porphyritic adamellite was sampled for this investigation, the following summary does not include the even-grained phase described by Mackay (1964). However, major differences between the two types appear to be few.

In the porphyritic adamellite pale pink subhedral potash feldspar megacrysts comprise about 10% of the rock. They are tabular, with lengths of up to 5–7 cm, and are set in an overall grey groundmass of grains generally up to 2–5 mm across. The megacrysts also occur as porphyroblasts in, and across the margins of, mafic and granitic or adamellitic xenoliths. These megacrysts are microperthitic and poikilitic (or poikiloblastic), with inclusions of quartz, plagioclase, biotite and sphene. Mackay (1964) and Phillips and Carr (1973) have given optical and x-ray data for this orthoclase, the composition of which varies from Or_{88} to Or_{93} (Mackay, 1964, p. i). Carlsbad twins are very prominent. The megacrysts contain well-developed myrmekite, and some possess rapakivi texture.

Table 1

Modal analyses of rocks from the adamellite at Yetholme

Mode	1	2	3	4	5	6
	Modal percentages					
Quartz	33·0	29·7	34·8	35·0	38	tr*
K-feldspar	23·5	31·2	35·0	36·0	32	3
Plagioclase	36·8	33·1	28·5	28·0	22	50
Biotite	5·7	5·1	1·32	1·0	7	—
Amphibole	tr	tr	—	—	—	Pyrox. 15
Magnetite+Ilmenite	0·61	0·55	0·29	<1·0	<1	9
Sphene	0·30	0·27	0·04	tr	—	Sec. Mins. 23
Apatite	0·03	0·03	0·01	—	—	
	99·94	99·95	99·96	100·0	100	100

* tr=trace.

Key:

1. Average of groundmass analyses for "megacrystalline granite" from tables 2, (3, 3A) and 4 of Mackay (1964), giving unit weight to the average determined here for each of her tables (29 analyses, 3 tables) (Durandal and Eusdale stocks).
2. As for 1, but recalculated to allow for 10% K-feldspar megacrysts to give a whole-rock analysis.
3. Average for "normal granite" from tables 3A and 5 of Mackay (1964), giving unit weight (N=13) to each analysis (Durandal stock).
4. Aplite (average of three analyses from Mackay (1964), table 8—calculated here on the basis of 31·3% quartz and 24·6% plagioclase in her sample P10) (Durandal stock).
5. Aplite (one analysis only). Sample sub-site YET 3 (Facer, 1976), U. of W. number R5622 (Durandal stock).
6. Dolerite (field name) (two analyses). Sample sub-site YET 5 (Facer, 1976), U. of W. number R5629 (Durandal stock). The mode and chemical data agree with Watts (1969) who described microdiorite dykes from the Yetholme/Mt. Tennyson area. Appreciable secondary mineralisation makes modal determination difficult. A 5 mm wide glassy margin occurs adjacent to the adamellite.

The groundmass contains subhedral to anhedral grains, including quartz, plagioclase, potash feldspar and biotite, with minor accessory minerals. In the groundmass the quartz is anhedral and is locally strained—for example at dyke contacts. The potash feldspar is also anhedral, and may be twinned on the Carlsbad law. Rim albite and myrmekite occur where the potash feldspar is in contact with the plagioclase, and intergranular albite and myrmekite are found where potash feldspar is adjacent to potash feldspar (cf. Phillips and Carr, 1973). The groundmass plagioclase is subhedral, and commonly forms aggregates with a blocky outline. Zoning is well-developed, with cores as calcic as An$_{40}$ to An$_{45}$ grading out to rims of about An$_{20}$. The cores show alteration to sericite and minor calcite. More sodic outer compositions are found as optically continuous myrmekite and albite occurring in partial rims adjacent to potash feldspar. Biotite forms subhedral to euhedral grains up to 2 mm across. It is pleochroic with α=straw, $\beta=\gamma$=dark red-brown. Minor patchy alteration of biotite to green chlorite is widespread. Accessory minerals are commonly contained in the biotite, and include apatite, zircon and sphene. Minor hornblende is present in some samples. The opaque grains are aggregates of slightly titaniferous magnetite (with partial alteration to hematite), with minor pyrite and molybdenite (Facer, 1976). This molybdenite is polytype 2H$_1$ (I. R. Plimer, personal communication, 1974; cf. Ayres, 1974). The sulphides are minor constituents, and are concentrated along joint surfaces, or associated with the strongly altered dyke rock. Traces of molybdenite have been observed on potash feldspar megacryst cleavage planes. The sulphides were thus apparently among the last minerals to be formed.

MINOR ROCK TYPES WITHIN THE DURANDAL ADAMELLITE

The minor rock types are aplite veins, pegmatite as patches or small veins generally less than one metre in length, "dolerite" dykes and xenoliths. Because Mackay (1964) and Watts (1969) have described the mineral composition of these in detail, only minor comments need be made here. Aplite modal data are presented in Table 1. The dolerite referred to here contains plagioclase (An_{54}) and accessory potash feldspar, and hence the term microdiorite (cf. Watts, 1969) is probably more apposite. The pegmatite was not studied in detail for this investigation, but trace element geochemical data are included in Table 3 (I. R. Plimer, personal communication, 1974).

Considerable variation between xenoliths is noticeable and this may partly reflect variation in assimilation and recrystallisation within the adamellite rather than simply different country rocks. Three-dimensional variation in grainsize and potash feldspar content in the xenoliths was evident when drilling samples for this investigation. The opaque mineral content of the xenoliths varies from 1% to approximately 5%, consisting primarily of anhedral to subhedral grains of magnetite. Hematite is a minor phase, both as discrete grains and as an alteration product of the magnetite. Mackay (1964) suggested that the predominant dark xenoliths may be derived from lamprophyric intrusions, although other country rocks are also present as xenoliths. (Lamprophyres were emplaced along the Cheshire Creek or Wiagdon Thrust, which is cut by the Durandal Adamellite.) The granitic (adamellite) inclusions are apparently examples of early-formed rock which were stoped into the main mass.

The aplite veins were considered by Mackay (1964) to fall into two groups—a steeply-dipping set, which cuts across potash feldspar megacrysts, and a set with shallow dips, the boundaries of which have been transgressed by the megacrysts (Mackay, 1964, p. 24). No noticeable mineralogical variation was observed in this investigation between aplite veins, and Mackay's (1964, p. 24) suggestion of a slight mineralogical difference may reflect her limited sampling opportunities caused by poor outcrop.

TABLE 2

Chemical analyses of rocks from a road cutting through the Durandal Adamellite at Frying Pan Creek, Yetholme

Analysis	1	2	3	4	5	6	7
Sub-site number	—	—	YET 4	YET 5	YET 5	YET 3	YET 5
Rock type	ADA	ADA	ADA	ADA	ADA	APL	DOL
2a—Oxide weight percentages							
SiO_2	67·99	72·06	68·30	70·85	69·71	75·10	44·70
TiO_2	0·53	0·09	0·40	0·41	0·39	0·07	1·71
Al_2O_3	14·98	16·27	15·90	13·95	14·66	13·50	14·99
Fe_2O_3	1·04	0·21	2·90	0·85	0·81	0·69	5·08
FeO	2·39	1·09		2·08	1·95	0·19	4·48
MnO	0·08	n.d.*	n.d.	0·06	0·04	n.d.	0·14
MgO	1·27	0·32	0·85	0·96	1·01	0·07	6·61
CaO	3·02	0·63	2·70	2·42	2·45	1·20	9·86
Na_2O	3·96	3·15	3·35	3·64	2·78	3·05	2·52
K_2O	3·18	4·91	3·80	3·90	4·15	4·85	1·21
H_2O+	1·04	1·24	n.d.	0·85	1·41	n.d.	6·16
H_2O-	0·28	0·17	n.d.	0·16	0·20	n.d.	1·29
P_2O_5	0·19	0·11	0·14	0·14	0·14	0·01	0·96
CO_2	0·08(1)	0·01(1)	n.d.	n.d.	n.d.	n.d.	n.d.
Total	100·03	100·26	98·34	100·27	99·70	98·73	99·71
Specific Gravity	—	—	2·66	2·66	2·67	2·61	2·76

TABLE 2—*continued*

Chemical analyses of rocks from a road cutting through the Durandal Adamellite at Frying Pan Creek, Yetholme

Analysis	1	2	3	4	5	6	7
Sub-site number	—	—	YET 4	YET 5	YET 5	YET 3	YET 5
Rock type	ADA	ADA	ADA	ADA	ADA	APL	DOL
2b—Norm percentages							
Q	23·90	32·69	27·61	27·55	30·23	36·15	0·06
or	18·79	29·02	22·46	23·05	24·52	28·66	7·15
ab	33·51	26·65	28·35	30·80	23·52	25·81	21·32
an	13·24	2·34	12·48	10·21	11·24	5·89	26·02
di	—	—	—	0·73	—	—	13·06
hy	5·97	2·48	2·12	4·58	4·86	0·17	11·81
mt	1·51	0·30	—	1·23	1·17	0·41	7·37
hm	—	—	2·90(2)	—	—	0·41	—
il	1·01	0·17	—	0·78	0·74	0·13	3·25
ru	—	—	0·40(2)	—	—	—	—
ap	0·44	0·25	0·32	0·32	0·32	0· 2	2·22
cc	0·18	0·02	—	—	—	—	— (3)
C(4)	0·18	4·92	1·70	—	1·48	1·08	—
(Water)	(1·32)	(1·41)	(n.d.)	(1·01)	(1·61)	(n.d.)	(7·45)
Total	100·03	100·26	98·34	100·27	99·69	98·75	99·71
An/(Ab+An)	28·32	8·08	30·57	24·90	32·33	18·58	54·96
An/(Or+Ab+An)	20·20	4·04	19·72	15·94	18·96	9·57	47·75
FeO/Fe_2O_3	2·298	5·190	— (5)	2·447	2·407	— (5)	0·882

* n.d.=not determined ; analyses by x-ray fluorescence.

ADA=Adamellite ; APL=Aplite ; DOL=Dolerite or microdiorite.

(1) One analysis only.

(2) The presence of hematite and rutile in this norm arises because FeO and Fe_2O_3 were not determined separately.

(3) Non-determination of CO_2 precludes normative calcite, but it should be noted that modal calcite is present.

(4) Normative corundum is unreal in these rocks. Its presence is apparently caused by excess Al_2O_3.

(5) Non-determination of separate FeO and Fe_2O_3 precludes determination of this ratio.

KEY :

1. Adamellite—average of two analyses from a representative sample of fragments. (Anal. S. E. Shaw.) U. of W. number R5616.
2. Adamellite—average of two analyses. (Anal. I. R. Plimer.)
3. Adamellite—small sample (about 2 kg), but as representative as possible. (Anal. B. Clift.) U. of W. number R5625.
4. Adamellite—small sample (about 3·5 kg) of adamellite about 10 cm W of the dolerite dyke (analysis 7). (Anal. S. E. Shaw.) U. of W. number R5627.
5. Adamellite—small sample (about 2 kg) of adamellite about 5 m E of the dolerite dyke (analysis 7). (Anal. S. E. Shaw.) U. of W. number R5631.
6. Aplite—representative sample of 10 cm wide aplite vein (approximate orientation : strike 305°T, dip 85°SW). (Some joints were coated with secondary minerals—these coatings were avoided in this sample.) (Anal. B. Clift.) U. of W. number R5622.
7. Dolerite—dyke about 0·4 m wide (approximate orientation : 000°T, dip approximately vertical). (Same comment re joints as for analysis 6.) (Anal. S. E. Shaw.) U. of W. number R5629.

CHEMICAL COMPOSITION OF THE DURANDAL ADAMELLITE

Table 2a contains major oxide analyses from the main rock types of the Durandal Adamellite. CIPW norms are given in Table 2b, along with various ratios, such as feldspar ratios. Trace element data for the adamellite and for potash feldspar separated from four different phases in the stock (I. R. Plimer, personal communication, 1974) are presented in Table 3. Mackay (1964) concluded that chemical analyses would be of limited value in interpretation because of the difficulty in separating feldspar phases and inclusions. Such a problem (of analysing for major elements such as Na and Ca) might be overcome by analysing for trace elements because slight variations between phases may be more noticeable in the minor elements whereas variations of a few percentile points may not be apparent in the major elements.

Analysis 2 is distinctive among the adamellite analyses. This may have arisen because the material analysed represented a late stage of crystallisation. Mackay (1964, Chapter 6) presented a theoretical discussion in which megacryst growth (discussed further below) resulted in an increase in K and a decrease in Ca.

The CIPW norm for the dolerite (analysis 7) lends support to the name " microdiorite " (based on its mode) because of the minor normative quartz and orthoclase. The high water content and modal calcite agree with the suggestion (Watts, 1969) of deuteric alteration. It is possible that this dyke has caused minor contamination of the adamellite within a few centimetres of the contact because analysis 4 yields minor normative diopside, and the dyke contains modal augite or diopsidic augite, and normative diopside. The radiometric age of the dyke (298±10 My ; Facer, 1976) is similar to the average age for the granitic phases of about 312 My and thus its emplacement occurred near the end of the main intrusive phase. Despite the sharp contact between the dyke and the adamellite (like some of the aplite veins) there is some hand specimen and thin section evidence of minor "mixing " between the adamellite and the dyke, although this may be restricted to minor stringers of dyke material in the adamellite.

The trace element data (Table 3) suggest that there are appreciable differences between the whole rock and the separated potash feldspar. For U and Th,

TABLE 3

Trace element distribution in the Durandal Adamellite and feldspar separates from a road cutting at Frying Pan Creek, Yetholme

Analysis	2	8	9	10	11
	Whole rock	Potash Feldspar separates			
		Megacrysts	Groundmass	Pegmatites	Xenolith
Trace elements, parts per million					
Y ..	28	bld*	2	3	bld
Sr ..	29	57	65	69	67
Zr ..	82	<1	bld	4	2
U ..	7†	<1	<1	bld	bld
Rb ..	322	557	573	596	566
Th ..	19	<1	bld	bld	bld
Pb ..	31	39	46	43	67
Ga ..	20	25	24	24	29
Zn ..	14	6	bld	10	4
Cu ..	7†	<1	18	4	bld

* bld = below the level of detection.

KEY :

All analyses by I. R. Plimer using X.R.F. techniques standardised against U.S. Department of Commerce, National Bureau of Standards 70a potassium feldspar, U.S. Geological Survey rocks W1, G2, DTS-1 and GSP-1. The Pb values may be high due to contamination during analysis (I. R. Plimer, personal communication, 1974).

2. Adamellite—average of two analyses, cf. analysis 2 in Table 1. (†The values for the two analyses were close, apart from U, 9 ppm and 4 ppm and Cu, 5 ppm and 9 ppm.)

8. and 9. Feldspar crystals separated from the adamellite—megacrysts (8) and groundmass (9).

10. Feldspar crystals separated from a very narrow (few cm wide) quartz-perthite pegmatite.

11. Feldspar megacryst from within a xenolith.

which are higher in the whole rock, and Sr which is lower, these differences are perhaps a little unusual. Mason (1958, p. 134) observed that U and Th both tend to be concentrated in pegmatites, and (p.131) that Sr tends to be concentrated in plagioclase (and hence presumably should be higher in the whole rock). Within the group of feldspar separates only Cu, Pb and Zn show any noteworthy difference between the feldspars from the four phases (megacryst, groundmass, pegmatite and xenolith).

HEAT GENERATION

Bunker *et al.* (1975) determined heat generation in a number of Australian crystalline rocks, including the Bathurst batholith. The heat production H in μcal/g-yr was derived from the expression (Bunker *et al.*, 1975, p. 2)

$$H = 0{\cdot}73\ U(\text{ppm}) + 0{\cdot}20\ Th(\text{ppm}) + 0{\cdot}27\ K(\%) \qquad (1)$$

using the abundance of the " radioelements " K, U and Th. Heat generation units (1 hgu $=10^{-13}$ cal/cm^3 sec $=0{\cdot}418$ μW/m^3) can be determined from H of equation (1) by multiplying by (density/3·156).

In their table 2–2, Bunker *et al.* (1975) gave " radioelement " abundances and H determinations for a number of samples from the University of Sydney collection of Bathurst batholith samples. Using the data from Tables 2 and 3, and table 2–2 of Bunker *et al.* (1975), heat generation data for the Durandal Adamellite are presented in Table 4.

TABLE 4

Heat-generation data for rocks from the Durandal Adamellite

No.	Locality		Chemical Data			Heat Generation	Reference
	S. Lat.	E. Long.	U(ppm)	Th(ppm)	K(%)	hgu*	
1.	33°27′	149°50′	3·63	17·26	3·20	5·88	Bunker *et al.* (1975)
2.	33°27′	149°49′	7·00	19·00	3·31	8·27	This study
3.	Bathurst batholith					7·43	Bunker *et al.* (1975) and this study

* 1 hgu $=0{\cdot}418$ μW/m^3 (Bunker *et al.*, 1975, p. 2).

KEY:

Entry 1. The hgu is calculated from Table 2·2 of Bunker *et al.* (1975), assuming an SG of 2·663.

Entry 2. U and Th—2 analyses; K—7 analyses; SG=2·663.

Entry 3. Simple arithmetic average, assigning unit weight to the localities given by Bunker *et al.* (1975), and using the average of their two Tarana results and the average of entries 1 and 2. SG was assumed to be 2·67.

DISCUSSION AND CONCLUSIONS

One of the most distinctive features of the Durandal Adamellite is the presence of the potash feldspar megacrysts. Mackay (1964, p. ii) concluded that " the potash feldspar megacrysts . . . grew at a late stage, in the solid state, due to the action of volatiles expelled from the unsolidified magma beneath ". Field and hand-specimen evidence cited by Mackay (1964), and evidence studied in this investigation, included the presence of small xenoliths of the groundmass (or xenocrysts) within the megacrysts, and the presence of these megacrysts in xenoliths and across the xenolith boundaries. Mackay (1964, p. 24) also observed megacrysts crossing some aplite vein margins. In her investigation Mackay (1964) concentrated on the mineralogical characteristics of these megacrysts and presented a comprehensive outline of the growth of the potash feldspar grains after initial crystallisation of the adamellite. This late-stage growth was possible because the intrusion apparently behaved as a " closed " system without the extensive development of (cooling) joints. Thus the late-stage fluids could not be concentrated along such fractures and hence behaved as an " ionic fluid " permeating the whole mass and effecting noticeable ionic exchange and replacement. Some emplacement of aplite veins and dolerite or microdiorite dykes possibly occurred after growth of potash feldspar megacrysts. It is suggested here that the sulphide minerals (especially molybdenite) were the last minerals to be developed.

Chemical data (Tables 2 and 3) tend to confirm the conclusions of Mackay (1964) based on the mineralogical and petrographic data. I. R. Plimer (personal communication, 1974) concluded that alkali exchange had been complete (because there is little trace element difference between the different feldspars). This suggests that equilibrium (for example, Mackay's (1964) discussion of K replacing Ca) was at least close to being achieved during final cooling of the xenolith-bearing adamellite. It may be that, although the potash feldspar grains apparently crystallised at slightly different times, most of this crystallisation occurred from a single system allowing full exchange between late-stage fluids and earlier-formed crystals. Hence at least many of the potash feldspar megacrysts in the Durandal Adamellite are apparently not of intratelluric origin, which Joplin (1931) suggested may be the origin of at least some potash feldspar phenocrysts in a porphyritic granite at Hartley.

Calculated values of heat generation in the Durandal Adamellite, and in the whole Bathurst batholith, vary between samples. In the case of the Durandal Adamellite this could represent variation in potash feldspar content, although Mackay's (1964) results and Tables 1 and 2 suggest that there is not a simple relationship between potash feldspar and heat generation. The trace element data (Table 3) indicate no noteworthy difference in Th and U between potash feldspar from four different " sites " within the adamellite. Th and U contents in the whole rock (porphyritic adamellite) are noticeably higher than in the potash feldspar. Hence, as the heat generated by the K-content rises as a result of increased potash feldspar content, the heat generated by the Th and U falls. For the Durandal Adamellite the Th and U are the main contributors to heat generation, suggesting that its variation is caused by variation in those two elements. This situation seems to obtain for other rocks from the Bathurst batholith, although further work would be needed to confirm this suggestion.

The heat generation of the Bathurst batholith is at least as high as, and in some cases appreciably higher than, other intrusive rocks from the New South Wales portion of the Eastern (Heat-Flow) Province of Sass *et al.* (1976) (see Bunker *et al.*, 1975 and Sass *et al.*, 1976). Unfortunately no heat-flow data are available for the batholith (Munroe *et al.*, 1975), although a shallow diamond drill hole at Lat. 33° 34′S, Long. 149° 34′E just south of the batholith yielded a corrected heat-flow of 1·5 hfu (1 hfu $=10^{-6}$ cal/cm^2 sec $=41\cdot8$ mW/m^2, Sass *et al.*, 1976). This value is less than those obtained for the Sydney Basin (Munroe *et al.*, 1975). Sass *et al.* (1976, p. 77) concluded that there was " increasing heat flow from north to south " across New South Wales. However, it is considered here that additional thermal data from igneous rocks of the Tasman geosyncline and the New England region need to be accumulated before such trends are more firmly established, and such a study is in progress. The (relatively) high heat generation for the Durandal Adamellite and the Bathurst batholith, and the (relatively) high heat-flow for the Sydney Basin may be related. As well as being close to a zone of moderate seismicity, the high heat-flow values for the Sydney Basin may reflect the high heat generation by the batholith, which forms at least part of the basement to the basin.

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